PORTLAND CEMENT ASSOCIATION, 33 West Grand Avenue, Chicago, Illinois 60610

cement mason's manual

for residential construction

Edward J. Leonard, general president of the Operative Plasterers' and Cement Masons' International Association of the United States and Canada.
—Chase, Ltd., photo

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International Association of the United States and Canada

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Portland Cement Association
33 West Grand Avenue
Chicago 10, Illinois

Gentlemen:

During the final stages in the preparation of your new publication, "Cement Masons' Manual for Residential Construction", we had the opportunity of reviewing the text and illustrations. We were delighted with the Manual and believe it will be a most valuable tool for the use of our Industry.

We know our membership, oldtimers as well as newer members, will profit by reading the Manual. Our apprentices and our apprentice training programs should also make good use of the Manual which we find is written in simple straightforward language and well illustrated with many photographs of actual on-the-job practices. We congratulate you upon this excellent Manual.

Sincerely yours,

Edward J. Leonard

Edward J. Leonard
General President

John J. Hauck

John J. Hauck
Secretary-Treasurer

contents

The activities of the Portland Cement Association are limited to scientific research, the development of new or improved products and methods, technical service, promotion and educational effort (including safety work), and are primarily designed to improve and extend the uses of portland cement and concrete. The manifold program of the Association and its varied services to cement users are made possible by the financial support of its member companies in the United States and Canada, engaged in the manufacture and sale of a very large proportion of all portland cement used in these two countries. A current list of member companies will be furnished on request.

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History of Portland Cement

Cementing materials have been used since the dawn of civilization. The famous Appian Way, the great system of aqueducts and other cement-bonded structures built by the Romans are today in an excellent state of preservation.

Despite the early use of these materials, little was known of their chemistry, and no substantial advance was made in the manufacture of cementing materials from the time of the Romans until 1756. In that year, John Smeaton, who had been employed by the English government to build a lighthouse in the English Channel, discovered that a mixture of limestone and a certain amount of clay, when burned, would harden into a solid mass under water as well as in air. This discovery of Smeaton's led the way to rapid improvement of limes and cements for masonry construction.

In 1796 James Parker of Northfleet, England, obtained a patent for the manufacture of a cementing material he called Roman cement and which later became known as natural cement. Parker's process consisted of burning certain stone or clayey products called "nodules of clay" in an ordinary lime kiln, and then grinding the clinkers to a powder. Cement made in this way rapidly gained favor among engineers and builders, and natural cement plants sprang up all over the continent of Europe, in England, and later, about 1818, in the United States.

In 1824 Joseph Aspdin took out a patent in England for the manufacture of an improved cement, produced by heating a mixture of limestone and clay and crushing the resulting product to a fine powder. To this powder he gave the name of *portland cement,* because when it hardened it produced a yellowish-gray mass resembling in appearance the stone found in various quarries on the Isle of Portland, England. Therefore Aspdin is generally recognized as the father of the modern portland cement industry.

Aspdin appears to have been the first to realize that superior hydraulic properties were obtainable by more intense burning of the limestone-clay mixture, which produced a harder substance with better-fused ingredients than was obtained by the earlier process. However, his cement was not uniformly sound because there still remained small pieces of the harder-burned clinker. It remained for Isaac Johnson to discover in about 1845 that the harder particles, after weathering and suitable mechanical grinding, yielded a cement of superior qualities. Johnson therefore is more nearly the discoverer of the portland cement we know.

In this country the cement industry began with the discovery in 1818 of a natural cement rock near Chitenango, N.Y., by Canvass White, an engineer on the Erie Canal. In 1825, cement rock was found in Ulster County, N.Y., and in 1828 a mill was built in Rosendale, N.Y.

In the spring of 1866, D. O. Saylor, Esaias Rehrig and Adam Woolever, all of Allentown, Pa., formed the Coplay Cement Co. and located a mill near Allentown for the manufacture of natural cement. Saylor began in the 1870's to experiment on making portland cement from the rock in the quarries. After many experiments and trials, true portland cement was produced in 1875. This was the first portland cement made in the Lehigh district and probably in the United States.

This, then, was the small beginning of the American portland cement industry, which has grown from a production of about 83,000 bbl. in 1880 to more than 325,000,000 bbl. in 1959. (One barrel weighs 376 lb. and is equal in volume to four sacks. Each sack weighs 94 lb. and is equal to 1 cu.ft. in volume.)

Modern portland cement is a finely pulverized material consisting principally of compounds of lime, silica, alumina and iron. Combined with water, portland cement reacts chemically and hardens into a solid mass.

materials for concrete

TYPES OF PORTLAND CEMENT

Portland cement is manufactured from carefully selected materials under closely controlled processes. The process starts by mixing limestone or marl with such other ingredients as clay, shale or blast furnace slag in proper proportions and then burning this mixture in a rotary kiln at a temperature of approximately 2700 deg. F. to form a clinker. The clinker is cooled and then pulverized, with a small amount of gypsum added to regulate the setting time. The pulverized product is the finished portland cement. It is ground so fine that nearly all of it will pass through a sieve with 40,000 openings to the square inch. When portland cement is mixed with water, a paste is formed which first sets (becomes stiff) and then hardens for an indefinite period. The setting and hardening are brought about by chemical reactions between the cement and water, called hydration.

Each manufacturer of portland cement uses a trade or brand name under which the product is sold. Portland cements are made to meet the American Society for Testing Materials' Standard Specifications, ASTM Designation:

C 150 Portland Cement, Types I through V
C 175 Air-Entraining Portland Cement
C 205 Portland Blast-Furnace Slag Cement
C 340 Portland-Pozzolan Cement

The first of these specifications, C 150, covers five types of portland cement:

Type I—Normal portland cement. This is a general purpose cement suitable for all uses when the special properties of the other types are not required. It is used in pavement and sidewalk construction, reinforced concrete buildings and bridges, railway structures, tanks and reservoirs, culverts, water pipe, masonry units, and for all uses of cement or concrete not subject to sulfate attack from soil or waters or where the heat generated by the hydration of the cement will not cause an objectionable rise in temperature.

Type II—Modified portland cement. This cement has a lower heat of hydration than Type I and generates heat at a slower rate. It also has improved resistance to sulfate attack. It may be used in structures of considerable size such as large piers, heavy abutments and heavy retaining walls, to minimize temperature rise, especially when the concrete is placed in warm weather. In cold weather when the heat generated is an advantage, Type I cement may be preferable. Type II cement is also intended for places where added precaution against moderate sulfate attack is important, as in drainage structures where sulfate concentrations in ground waters are higher than normal but are not unusually severe.

Type III—High-early-strength portland cement. It is used when high strengths are desired at very early periods—from one to three days. It is used when it is desired to remove forms as soon as possible or to put the concrete into service quickly, in cold weather construction to reduce the period of protection against low temperatures, and when high strengths desired at early periods can be secured more satisfactorily or more economically than by using richer mixes of Type I cement.

Type IV—Low-heat portland cement. This is a special cement for use where the amount and rate of heat generated must be kept to a minimum. The development of strength is also at a slower rate. It is intended for use only in large masses of concrete such as large gravity dams where temperature rise resulting from the heat generated during hardening is a critical factor.

Type V—Sulfate-resistant portland cement. This is a special cement intended for use only in construction exposed to severe sulfate action, such as in some western states having soils or waters of high alkali content. It has a slower rate of strength gain than normal portland cement.

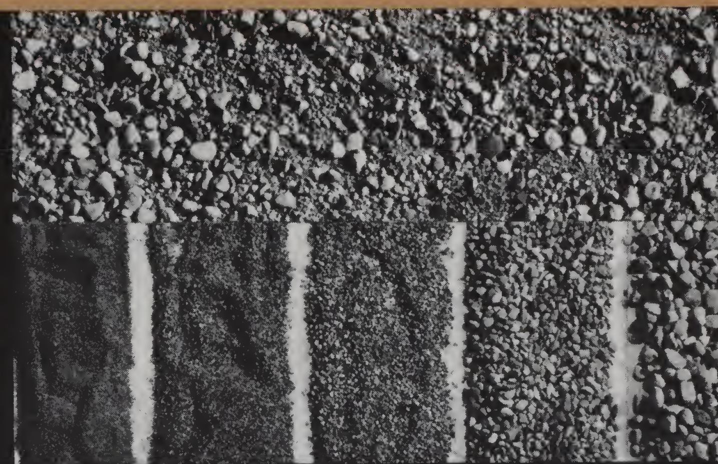
Air-Entraining Portland Cements

ASTM C 175 covers three types of air-entraining portland cement—Types IA, IIA and IIIA. These correspond to Types I, II and III respectively in ASTM C 150. In these cements, small quantities of air-entraining materials are incorporated by intergrinding them with the clinker during manufacture. They have been developed to produce concrete resistant to severe frost action and to effects of applications of salt for snow and ice removal. Concrete made with these cements contains tiny, well-distributed and completely separated air bubbles. The bubbles are so minute there are many billions of them in a cubic foot of the concrete.

Portland Blast-Furnace Slag Cement

ASTM C 205 covers two types of cement—Type IS, portland blast-furnace slag cement and Type ISA, air-entraining portland blast-furnace slag cement. In these cements, granulated blast-furnace slag (a product obtained by rapidly chilling or quenching molten slag in water, steam or air) of selected quality is interground

FIG. 2. Sample of well-graded sand before and after separation into various sizes. Particles vary from dust to those just passing the No. 4 sieve (approximately ¼ in.).



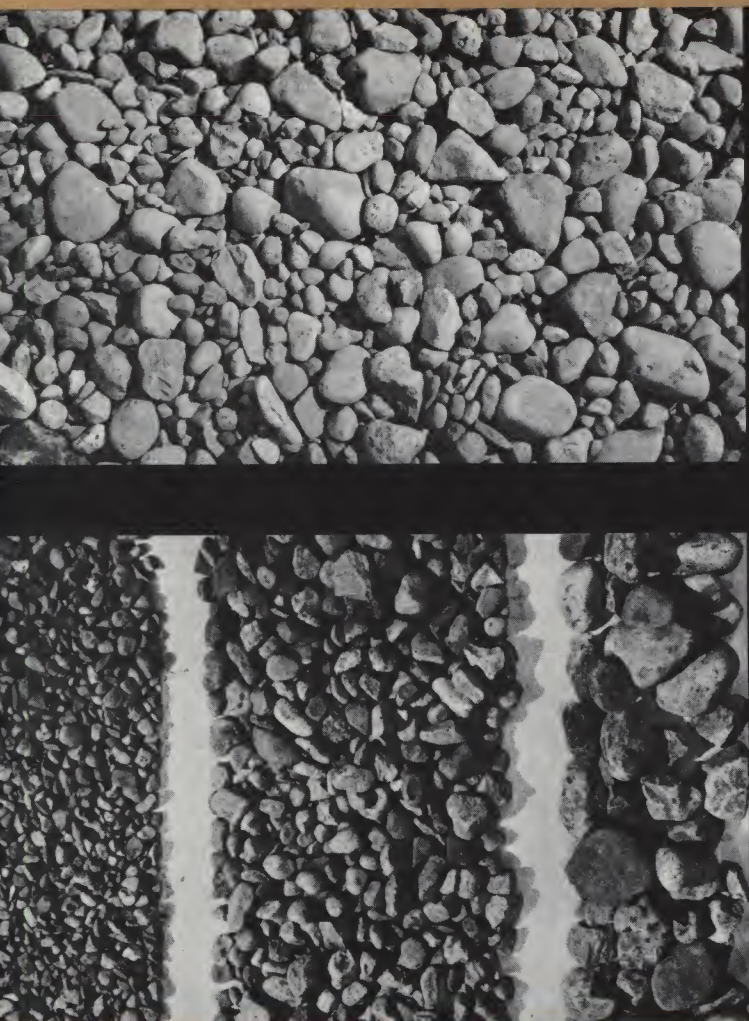


FIG. 1. This is how a well-graded coarse aggregate looks before *(above)* and after being separated *(below)* into three sizes. From left to right in the separated aggregate: ¼ to ⅜ in., ⅜ to ¾ in., ¾ to 1½ in. Note how the smaller pieces fit among larger ones in the mixed aggregate.

FIG. 3. Sample of sand which lacks particles larger than 1/16 in. *(above)* and after separation *(below)* into four sizes. More cement is required when sand is fine. This is not a good concrete sand.

with portland cement clinker. These cements can be used for the same type of concrete work as Type I or Type IA portland cement.

Portland-Pozzolan Cement

ASTM C340 covers two types of cement—Type IP, portland-pozzolan cement and Type IPA, air-entraining portland-pozzolan cement. In these cements, pozzolan (such as volcanic ash or volcanic rock) is blended with ground portland cement clinker. This cement is used largely for underwater structures, such as bridge piers and dams.

CONCRETE AGGREGATES

The selection of aggregates is of particular importance in the making of concrete. Both the cost and the quality of the concrete are affected by the kind of aggregates selected. Aggregates should be used from sources known to make long-lasting concrete, or ob-

tained from reliable dealers. If it is necessary to use aggregates of unknown quality, they should be carefully examined and tested to make sure they are suitable for making concrete. Aggregates for concrete should meet the requirements of the Standard Specifications for Concrete Aggregates, ASTM Designation: C33. These specifications place limits on allowable amounts of damaging substances and also cover requirements as to grading, strength and soundness.

WATER

Mixing water should be clean and free from oil, alkali or acid. In general, water that is fit to drink is suitable for mixing with cement. However, water with excessive quantities of sulfates should be avoided even though it may be fit to drink.

ADMIXTURES

An admixture is defined in ASTM Designation C125 as "A material other than water, aggregates, and portland cement (including air-entraining portland cement and portland blast-furnace slag cement) that is used as an ingredient of concrete and is added to the batch immediately before or during its mixing."

Admixtures are sometimes used in concrete for a variety of purposes, such as to improve workability, reduce segregation, entrain air, or accelerate or retard setting and hardening.

However, in considering the use of admixtures in concrete, remember that: (1) a change in type of cement or amount of cement used, or a modification of aggregate gradation or mix proportions may offer the surest and most economical approach to the desired objectives; (2) many admixtures affect more than one property of concrete, sometimes hurting desirable properties; (3) the effects of some admixtures are changed by such things as wetness and richness of mix, by aggregate gradation and by character and length of mixing; (4) some admixtures will not react the same with all cements, even of the same type, and (5) accordingly, specific effects that will result from the use of an admixture can seldom be predicted accurately.

Admixtures can be divided into 10 groups according to purpose. Listed below are all 10 groups, but only the first three will be discussed, as they are the ones the cement mason will meet most frequently.

1. Accelerators
2. Retarders
3. Air-entraining agents
4. Gas-forming agents
5. Cementitious materials
6. Pozzolans
7. Alkali-aggregate expansion inhibitors
8. Dampproofing and permeability-reducing agents
9. Workability agents
10. Grouting agents
11. Other agents possessing specific properties not listed above

Accelerators

Accelerators increase the rate of early strength development in concrete to: (1) reduce the waiting time for finishing operations to be started; (2) permit earlier removal of forms and screeds; (3) reduce the required period for curing in certain types of work; (4) advance the time when a structure can be placed in service; (5) partially compensate for the slow gain in strength of the concrete even with proper protection during cold weather; and (6) reduce the period of protection required for initial and final set in emergency repair and other work.

In many cases, it must be decided whether to (1) use an admixture; (2) increase the cement content; (3) use high-early-strength cement; (4) provide greater protection or a longer curing period; or (5) use any combination of these.

Calcium chloride is generally used to accelerate the time of set and to increase the rate of strength gain. It should meet the requirements of the Standard Specifications for Calcium Chloride, ASTM Designation: D98, and the amount used should vary between 1 and 2 lb. per sack of cement. Any addition of more than 2 lb. per sack of cement should not be permitted. Calcium chloride should always be added in solution—*never in dry form*—as part of the mixing water to ensure uniform distribution throughout the concrete. Calcium chloride should never be considered as an antifreeze. To appreciably lower the freezing point of concrete would require the use of so much calcium chloride that the concrete would be ruined. Instead, measures should be taken to prevent the concrete from freezing, such as using protective covers and insulated forms, and heating the materials and the surrounding air.

Retarders

The principal uses of admixtures having a retarding effect on the set of cement in concrete are to overcome the accelerating effect that temperature has on setting during hot weather concreting operations and to delay early stiffening action of concrete placed under difficult conditions. In addition, retarder solutions are sometimes applied directly to the surface of the concrete to retard the set of a surface layer of mortar so that it can be readily removed by brushing, thus exposing the aggregate and producing textured surface effects.

A wide variety of chemicals are mentioned in current literature as having a retarding influence on the normal setting time of portland cement. Some of these have been found variable in action, retarding the set of certain cements and accelerating the set of others. Unless experience has been gained with a retarder to determine the extent of its effects on the setting time

and other properties of the concrete, its use as an admixture should not be attempted without technical advice or preferably advance experimentation with the cement and other concreting materials involved.

Air-Entraining Agents

Air-entraining admixtures used in concrete will improve the workability and durability, and in the case of exposed flatwork will produce a concrete resistant to severe frost action and to the effects of applications of salt for snow and ice removal.

Properly proportioned air-entrained concrete contains less water per cubic yard than non-air-entrained concrete of the same slump, and has better workability. This results in a more solid, weather-resistant, blemish-free surface. It can be handled and placed with less segregation of materials and less tendency to bleed.

These properties indirectly aid in promoting durability by increasing the uniformity of the concrete.

When using air-entraining cements or admixtures containing air-entraining agents, care must be taken that the quantity of water in the concrete mix is adjusted to maintain the desired slump. Such mix design and adjustments should be made only by a qualified engineer or concrete technician.

Because of its proven service record, both in the laboratory and field, and because of its increased workability and durability, air-entrained concrete is strongly recommended for all concrete, regardless of exposure conditions. Where freezing and thawing are encountered, its use should be required. Air-entraining cement or an air-entraining admixture (conforming to ASTM C260) should be used to obtain the following proper percentages of air entrainment:

Maximum size aggregate	Entrained air
3/8 in.	7½ ± 1 per cent
3/4 in.	6 ± 1 per cent
1½ in.	5 ± 1 per cent

fundamentals of quality concrete

Although the cement mason may not design the concrete mix, it will be to his advantage to understand some of the fundamentals of quality concrete. He should know something of selecting materials, proportioning and mixing.

SELECTING MATERIALS

The materials used to make concrete are portland cement, water, fine aggregate and coarse aggregate.

Portland Cement

Each sack of portland cement contains 94 lb. of cement and is equal to 1 cu.ft. in volume. Portland cement should be free of all lumps when used. If it contains lumps that cannot be pulverized between thumb and finger, it should not be used. Portland cement must be stored in a dry place. The various types of portland cement and their specific uses have been explained in detail earlier in the text.

Water

Water should be clean and free of oil, acid or alkali. In general, water that is fit to drink is suitable for making concrete.

Aggregates

Fine aggregate consists of sand or other suitable fine material. A good concrete sand will contain particles varying uniformly in size from very fine up to 1/4 in. In well-graded sand the finer particles help fill the spaces between the larger particles. Good gradation of sand from coarse to fine is important for the workability of the concrete.

Coarse aggregate consists of gravel, crushed stone or other suitable materials larger than ¼ in. Coarse aggregates that are sound, hard and durable are best suited for making concrete. Those that are soft or flaky or wear away rapidly are generally unsatisfactory. However, when lightweight concrete is being used the ag-

gregates are usually porous in order to decrease the weight.

All aggregates, fine and coarse, should be clean and free of loam, clay or vegetable matter, since these foreign particles prevent the cement paste from properly binding the aggregate particles together. Concrete containing these objectionable materials will be porous and have low strength.

The maximum size of coarse aggregate depends on the kind of work for which the concrete is to be used. Coarse aggregate up to 1½ in. in size, for example, may be used in a thick foundation wall or heavy footing. In walls, the largest pieces should never be more than one-fifth the thickness of the finished wall section. For slabs the maximum size should be approximately one-third the thickness of the slab. The largest pieces of aggregate should never be larger than three-quarters of the width of the narrowest space through which the concrete will be required to pass during placing. This is usually the space between the reinforcing bars or between the bars and the forms. Coarse aggregate is well graded when particles range uniformly from 1/4 in. up to the largest size that may be used on the kind of work to be done.

The mixture of fine and coarse aggregates as taken from a gravel bank or crusher does not usually make good quality concrete unless it is first screened to separate the fine aggregate from the coarse and then recombined in the correct mix proportions. Most gravel banks contain an excess of sand in proportion to coarse material. This ungraded gravel, if taken directly from the gravel bank and used in making concrete, is called "skip-graded" aggregate. The use of skip-graded aggregate does not result in the most economical concrete, largely because the excess of fines requires more cement paste than would otherwise be necessary to produce concrete of a given quality. Aggregates for concrete should meet the requirements of the Standard Specifications for Concrete Aggregates, ASTM C 33.

AGGREGATE TESTS

Aggregates may be tested for quality. The silt test is used to detect the presence of too much extremely fine material. The colorimetric test is used to detect the presence of harmful amounts of vegetable matter.

In making the silt test, an ordinary quart milk bottle or quart canning jar is used (Fig. 4). Fill the container to a depth of 2 in. with a representative sample of dry sand to be tested. Add water until the bottle or jar is about three-fourths full. Shake vigorously for one minute, the last few shakes being merely horizontal movements of the container to level off the sand. Allow the jar to stand for an hour, during which time any silt present will be deposited in a layer above the sand. If this layer is more than 1/8 in. thick, the sand from which the sample is taken is not satisfactory for concrete work unless the silt is removed by washing. Sand containing gritty silt may be used for making concrete, but it is advisable to remove all silt.

In making the colorimetric test, fill an ordinary 12-oz. prescription bottle, such as druggists or physicians use, to the 4½-oz. mark with a sample of the sand. Add to this a 3 per cent solution of caustic soda until the 7-oz. mark is reached. The solution can be made by dissolving 1 oz. of sodium hydroxide (which can be purchased at a drug store) in 1 qt. of water, preferably distilled. Keep the solution in a glass bottle tightly closed with a rubber stopper.

Take care not to spill the sodium hydroxide solution; it can seriously burn the skin and is highly injurious to clothing, leather and most other materials.

As soon as the solution of sodium hydroxide is added to the sand, shake the contents of the bottle thoroughly and then allow it to stand for 24 hours. The color of the liquid will indicate whether the sand contains too great an amount of vegetable matter (Fig. 5). A colorless liquid indicates a clean sand free from vegetable matter. A straw-colored solution indicates some vegetable matter but not enough to be seriously objectionable. Darker colors mean that the sand contains detrimental amounts of vegetable matter and should not be used until it is washed and tested to show a color that indicates its suitability for use.

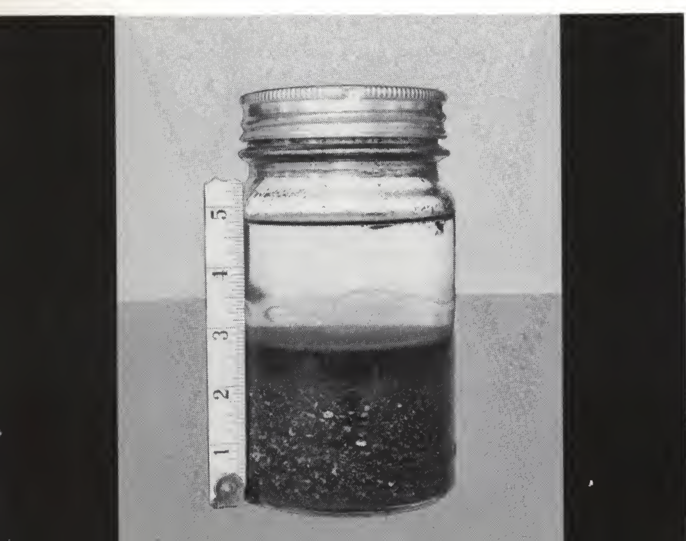


FIG. 4. A quart canning jar may be used to make the silt test.

FIG. 5. The color test is used to detect the presence of harmful amounts of organic matter in aggregates. Left, colorless—free from organic matter. Center, slightly straw colored—some organic matter but not enough to prove injurious. Right, dark liquid—unsatisfactory for concrete unless organic matter is washed out.

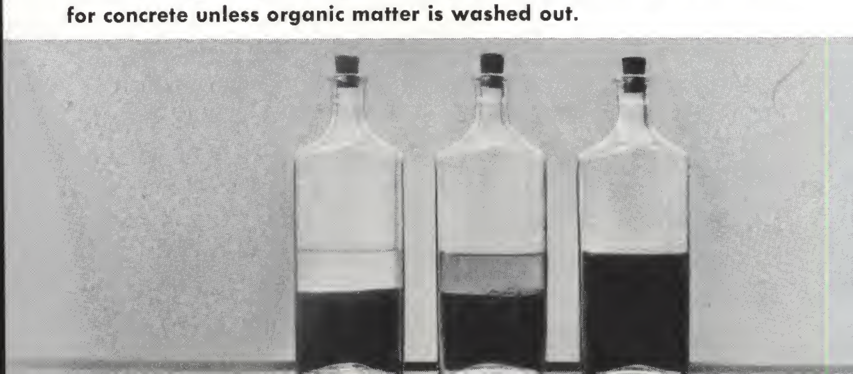


FIG. 6. If sand falls apart it is damp.

FIG. 7. If sand forms a ball it is wet.

FIG. 8. If sand sparkles and wets the hand it is very wet.

PROPORTIONING

Concrete is a mixture of fine and coarse aggregates surrounded and held together by hardened portland cement paste. With favorable temperatures, and continued presence of moisture during curing, a chemical reaction between the cement and water causes the paste to harden in the desired length of time. If too much water is added, the paste becomes thin or diluted and will be weak and porous when it hardens. A paste of this kind will not hold the particles of aggregate firmly together. Cement paste made with the correct amount of water has strong binding qualities to hold the particles of aggregate firmly together to make strong, dense, watertight concrete.

If the paste is strong and the aggregates hard, the concrete is strong. If the cement paste is watertight, the concrete is watertight. If the paste and aggregates are durable, the concrete is durable. Strength, durability, watertightness and wear resistance of the paste are controlled by the amount of water used per sack of cement in forming the paste.

There is a direct link between strength of the concrete and the relative quantities of water and cement in the mixture which is expressed by the *water-cement ratio strength relationship:*

> *For given materials and conditions of handling, the strength of the concrete is determined primarily by the ratio of the volume of mixing water to the volume of cement as long as the mixture is plastic and workable.*

In other words, if 6 gal. of water are used for each sack of cement in a mixture, the strength at a certain age is practically fixed, *as long as the mixture is plastic and workable* and the aggregates are strong, clean and made up of sound particles. More water means less strength and less water means greater strength.

Allowance for Moisture in the Aggregates

Most fine aggregates contain some water. Therefore allowance must be made for this moisture in determining the amount of water to be added to the mix. A simple test for determining whether sand is damp, wet or very wet is to press some together in your hand. If the sand falls apart after your hand is opened, it is damp (Fig. 6); if it forms a ball which holds its shape, it is wet (Fig. 7); if the sand sparkles and wets your hand, it is very wet (Fig. 8).

This same test is also used in determining water present in bank-run material.

The amounts of water to add when fine aggregate is damp, wet or very wet are as follows:

If mix calls for:	Use these amounts of mixing water, in gallons, when sand is:		
	Damp	Wet	Very wet
6 gal. per sack of cement	5½	5	4¼
7 gal. per sack of cement	6¼	5½	4¾

The amount of water in the fine aggregate plus the quantities shown above make the total of 6 or 7 gal. per sack of cement, depending upon which mix is used. If the sand is bone dry, the full 6 or 7 gal. of water should be used.

CONCRETE TESTS

Slump Test (ASTM C 143)

The slump test may be used as a rough measure of the consistency of concrete.

This test is not to be considered as a measure of workability, nor should it be used to compare mixes of

entirely different proportions or containing different kinds of aggregates. Any change in slump on the job indicates changes have been made in grading or proportions of the aggregates or in the water content. The mix should be corrected immediately to get the proper consistency by adjusting amounts and proportion of sand and coarse aggregate, care being taken not to change the total amount of water specified for mixing with each sack of cement. For residential construction, the slump should be from 2 to 5 in.

In making the slump test, the test specimen is made in a mold of 16-gage galvanized metal in the form shown in Fig. 9 (also known as a slump cone). The diameter is 8 in. at the base and 4 in. at the top, and the height is 12 in. The base and top are open. The mold is provided with foot pieces and handles as shown.

When the slump test is made, the concrete sample is taken immediately prior to placing in the forms. The mold is placed on a flat surface such as a smooth plank or slab of concrete, and is held firmly in place by standing on the foot pieces while filling it with concrete. The mold is filled with concrete to about one-third its height. Then the concrete is puddled with 25 strokes of a 5/8-in. steel rod about 24 in. long, bullet pointed at the lower end (Fig. 10). The filling is completed in two more layers, each layer being rodded 25 times and each rod stroke penetrating into the underlying layer. After the top layer has been rodded, it should be struck off with a trowel so that the mold is exactly filled. The mold is removed by gently raising it vertically immediately after being filled.

The slump of the concrete is measured, as shown in Fig. 11, immediately after the cone is removed. For example, if the top of the slumped pile is 4 in. below the top of the cone, the slump for this concrete is 4 in.

Compression Test (ASTM C31)

This test is to determine if the concrete has the specified compressive strength. Field control specimens of various ages determine the rate of strength gain and the effectiveness of job site curing.

In making the compressive strength field test a sample of the concrete is taken at three or more regular intervals throughout the discharge of the entire batch, except that samples are not to be taken at the beginning or end of discharge. The batch of concrete thus sampled is noted as to its location in the work, the air temperature and any unusual conditions that might be occurring at the time.

The compressive test specimen is made in a cylindrical mold that is watertight to prevent loss of water. Standard cylindrical molds are 6 in. in diameter by 12 in. in length if the coarse aggregate does not exceed 2 in. in nominal size. The mold is filled in three layers. Each layer is puddled with 25 strokes of a 5/8-in. round steel rod about 24 in. long, with bullet-pointed tip. Re-

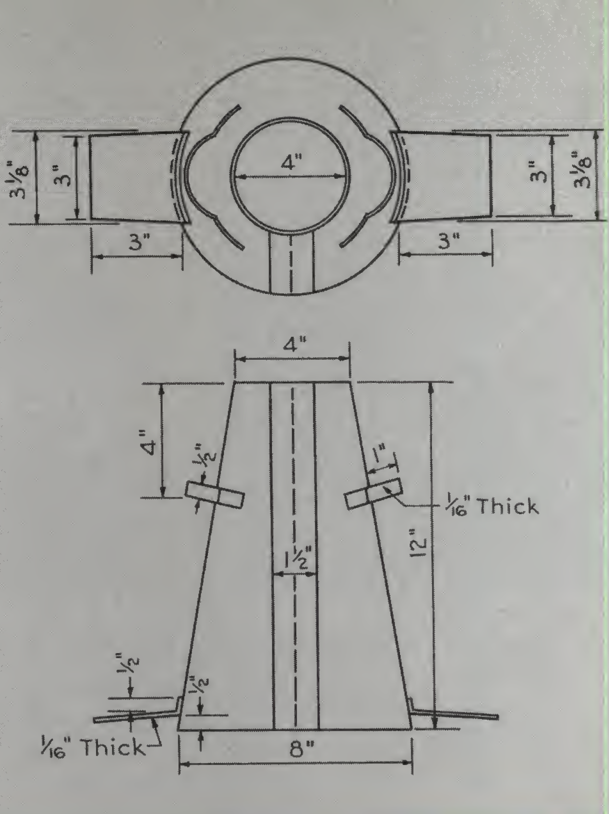


FIG. 9. Mold for slump test.

FIG. 10. The slump test shows consistency of concrete. Here, rodding concrete in cone ensures complete filling of the mold.

FIG. 11. Slump is measured from rod laid across the top of the slump cone. This amount of slump indicates a medium-wet concrete mixture.

inforcing rods or other tools should *not* be used as the puddle rod. After the top layer has been rodded, the surface of the concrete is struck off with a trowel and covered with a glass or metal plate to prevent evaporation.

Standard procedures provide for curing the specimens either in the laboratory or in the field. Laboratory curing gives a more accurate indication of the potential quality of the concrete. Field-cured specimens may give a more accurate interpretation of the actual strength in the structure or slab, but they offer no explanation as to whether any lack of strength is due to error in proportioning, poor materials or unfavorable curing conditions. On some jobs both methods are used, especially when the weather is unfavorable, in order to interpret the tests properly. The laboratory test result is the one that always prevails.

MIXING

All concrete should be thoroughly mixed until it is uniform in appearance and all materials are uniformly distributed. The time required for thorough mixing depends on several factors. Specifications usually require a minimum mixing time of 1 minute for mixers up to 1 cu.yd. capacity, with an increase of 15 seconds mixing time for each 1/2 cu.yd., or fraction thereof, additional capacity. The mixing period should be measured from the time all solid materials are in the mixer drum, provided all of the water is added before one-fourth the mixing time has elapsed.

Mixers should not be loaded above their rated capacity and should be operated at approximately the speeds for which they are designed. If the blades of the mixer become worn or become coated with hardened concrete, the mixing action will be less efficient. Badly worn blades should be replaced and hardened concrete should be removed before each run of concrete.

Under usual operating conditions, up to about 10 per cent of the mixing water should be placed in the drum before the aggregates and cement are added. Water should then be added uniformly with the dry materials, leaving about 10 per cent to be added after all other materials are in the drum. When heated water is used during cold weather this order of charging may require some modification to prevent flash setting of the cement. In this case, addition of the cement should be delayed until most of the aggregate and water have intermixed in the drum.

tools for horizontal surfaces

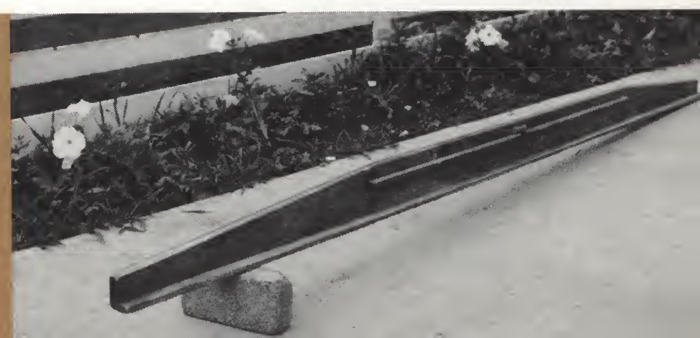
There are many tools for finishing concrete surfaces, but this manual will deal only with those tools that are used to finish horizontal concrete surfaces. In most cases, the apprentice cement mason will receive his initial on-the-job training primarily with flatwork finishing tools.

Straightedge

A straightedge (Fig. 12) or strike-off rod is usually a straight piece of 2x4 or a 1x4 with a 1/2x2-in. shoe strip attached to the bottom (Fig. 13). It can, however, be made of any straight piece of wood or metal that has sufficient rigidity. It is preferable to use a tool that has been specifically made as a straightedge instead of just a piece of lumber. The striking surface of a straightedge should always be straight and true. The straightedge should be longer than the widest distance between the screeds or edge forms. It is the first finishing tool used by the cement mason after the concrete is placed and is used to strike off or screed the concrete surface to proper grade.

FIG. 12. Straightedge or strike-off rod.

FIG. 13. The recommended straightedge.



Hand Tamper

After the concrete has been struck off, hand tampers (Fig. 14) can be used to compact the concrete into a dense mass. They are used on flatwork construction with low-slump concrete. Such concrete is usually quite stiff and is often difficult to work.

One common form of hand tamper is better known in the trade as a "jitterbug." Its base is usually made of a metal grill 6½ in. wide by 36 in. or 48 in. long. Tampers are used to force the large particles of coarse aggregate *slightly* below the surface in order to enable the cement mason to put the desired finish on the concrete surface. This tool should be used only with concrete having a very low slump—about 1 in.—and should be used to bring just enough mortar to the surface for proper finishing. The jitterbug or tamper should be used sparingly and in most cases is not recommended and not necessary, and the cement mason can proceed directly to darbying, the next step in quality finishing.

Darby

A darby (Fig. 15) is a long, flat, rectangular piece of wood, aluminum or magnesium from 30 to 80 in. long and from 3 to 4 in. wide with a handle on top. It is used to float the surface of the concrete slab immediately after it has been screeded, to prepare it for the next step in finishing. This tool should be used to eliminate any high or low spots or ridges left by the straightedge. It should also sufficiently embed the coarse aggregate for subsequent floating and troweling.

Bull Float

A bull float (Fig. 16) is a large, flat, rectangular piece of wood, aluminum or magnesium, usually 8 in. wide and 42 to 60 in. long with a handle 4 to 16 ft. in length. The function of the bull float is essentially the same as that of the darby but it enables the cement mason to float a larger section of a wide slab. The bull float is more commonly used outdoors or where there is enough room to use the long handle.

Edger

Edgers (Fig. 17) come in many sizes; all are about 6 in. long, and vary in widths from 1½ in. to 4 in., with lips from 1/8 in. to 5/8 in., and having radii from 1/8 in. to 1½ in. The curved-end edger is considered one of the more popular types. Edgers are used to produce a radius at the edge of a slab. This improves the appearance and reduces the risk of damage to the edge.

FIG. 14. Hand tamper, commonly called a jitterbug.

FIG. 15. Darby.

FIG. 16. Bull float.

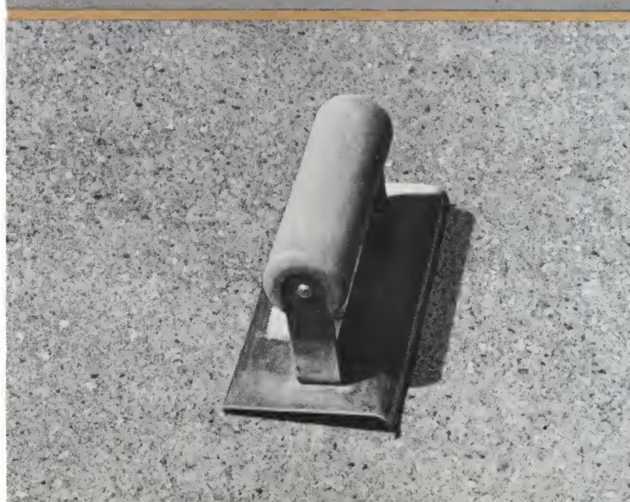


FIG. 17. Edger.


FIG. 18. Jointer or groover.

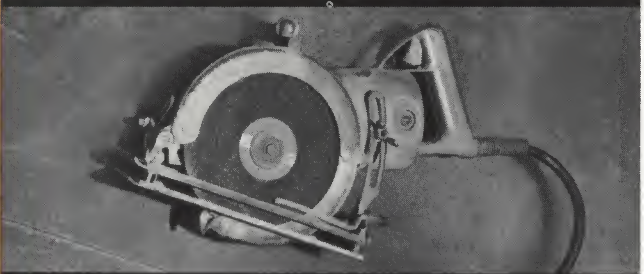


FIG. 19. Power joint cutter.


FIG. 20. Hand float.


FIG. 21. Wood float.

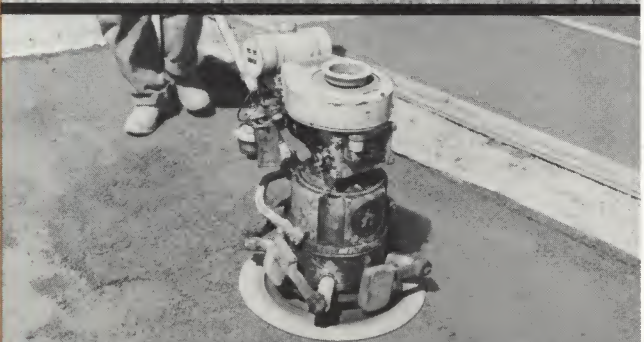


FIG. 22. Power float.

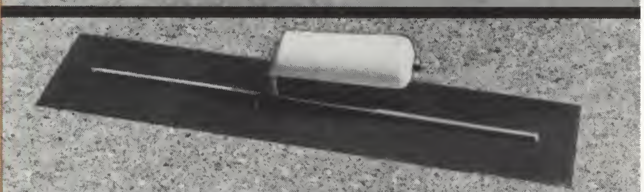


FIG. 23. Steel trowel.

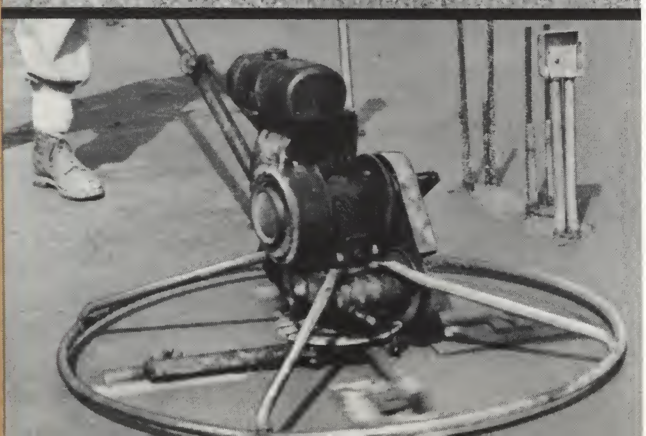


FIG. 24. Power trowel.

Jointer or Groover

Jointers (Fig. 18), sometimes called groovers, are about 6 in. long and vary from 2 to 4½ in. wide, and have shallow, medium or deep bits (cutting edges) running from 3/16 in. to 3/4 in. in depth. A jointer is used to cut a joint partly through fresh concrete. These joints, sometimes referred to as contraction or control joints, are used to predetermine the location of any possible cracks.

Power Joint Cutter

Another method of cutting joints in concrete slabs is with an electric or gasoline-driven saw (Fig. 19) fitted with a shatterproof abrasive or diamond blade. A power cutter produces a narrow joint that minimizes the possibilities of spalling at the joint due to traffic. The joint is cut in the concrete surface 4 to 12 hours after the concrete has hardened or as soon as the concrete surface will not be torn or damaged by the saw.

Hand and Power Floats

Hand floats are made of aluminum, magnesium or wood. Aluminum or magnesium floats (Fig. 20) are usually made in two sizes, 12 or 16 in. long by 3½ in. wide. Wood floats (Fig. 21) are 12, 15 or 18 in. long and 3½ or 4½ in. wide.

The hand float is used to prepare the concrete surface for troweling. Hand floats are also used for floating the concrete around pipes and columns and against walls which power floats cannot reach.

Power floats are driven by electricity or by gasoline engines. A power float has a rotating disk about 2 ft. in diameter (Fig. 22). Usually in residential construction a power trowel (Fig. 24) is used with the trowel blades modified for floating. These floating machines perform the same operations as hand floating, but cover larger areas in a shorter length of time.

After the concrete is stiff enough to support the weight of a man, the power float can be used to compact the concrete.

Hand and Power Trowels

The cement mason's steel hand trowel comes in many different sizes ranging from 10 to 20 in. long and 3 to 4¾ in. wide (Fig. 23).

Each size trowel has its own use. For the first troweling of concrete flatwork a wide trowel 16 to 20 in. long is generally used. For troweling the slab the last few times, most cement masons prefer a "fanning" trowel 14 to 16 in. long and 3 to 4 in. wide.

A power trowel has three or four rotating steel trowel blades (Fig. 24). They are powered by electricity or by gasoline engine.

The purpose of steel troweling is to give the surface a dense, smooth finish.

fundamentals of the use of transit and level

ESTABLISHING ELEVATIONS WITH A BUILDER'S LEVEL

Set up the instrument where locations for which elevations are to be determined may be seen through the telescope. Level up the instrument and take a reading on the measuring rod by means of the horizontal cross hair in the telescope. The rod is then moved to the second point to be established. Then the rod is raised or lowered until the reading is the same as the original. The bottom of the rod is then at the same elevation as the original point.

MEASURING DIFFERENCE IN ELEVATION

To obtain the difference in elevation between two points, such as *A* and *B* in Fig. 25, set up and level the instrument at an intermediate point *C*. With the measuring rod held on point *A* note the reading where the horizontal cross hair in the telescope crosses the graduation marks on the rod. Then with the rod held on point *B*, sight on the rod and note where the horizontal cross hair cuts the graduations on the rod. The difference between the reading at *A* (5 ft.) and the reading at *B* (5½ ft.) is the difference in elevation between *A* and *B*. Thus point *B* is 1/2 ft. lower than point *A*.

When, for any reason such as irregularity of the ground or a large difference in elevation, the two points whose difference in elevation is to be determined cannot be sighted from a single point, intermediate points must be used for setting up the instrument, as shown in Fig. 26.

ESTABLISHING POINTS ON A LINE WITH A TRANSIT

Level the instrument and center it accurately over a point on the line by means of a plumb bob. Then sight the telescope on the most distant visible known point of that line. Lock the horizontal motion clamp screw to keep the telescope on line, and place the vertical cross hair exactly on the distant point with the tangent screw. Then, by rotating the telescope in the vertical plane, the exact location of any number of stakes on that same line may be determined (Fig. 27).

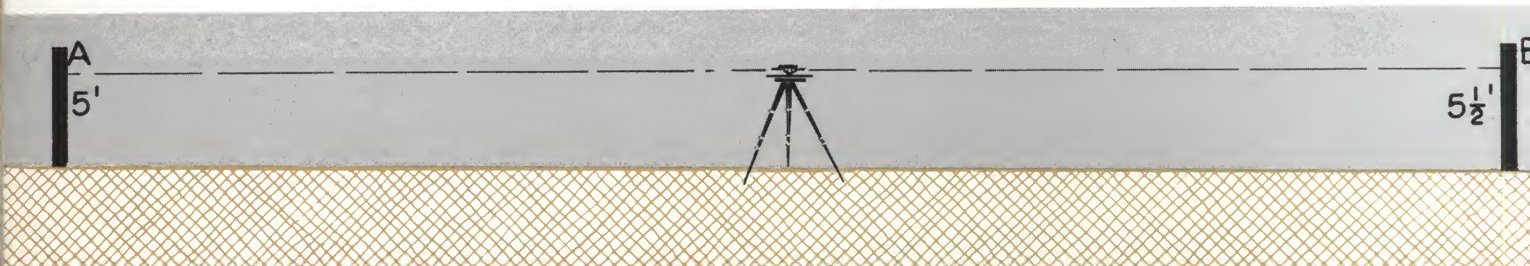


FIG. 25. Obtaining the difference in elevation between two visible points.

FIG. 26. Obtaining the difference in elevation between two points not visible to each other.

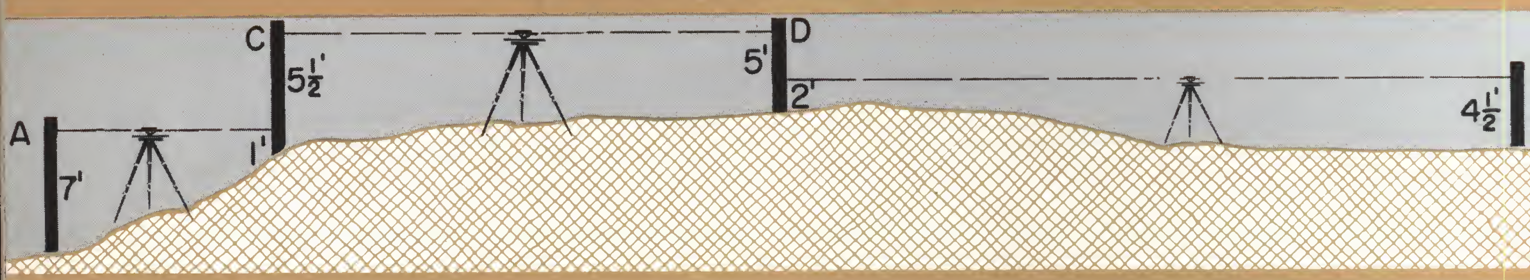
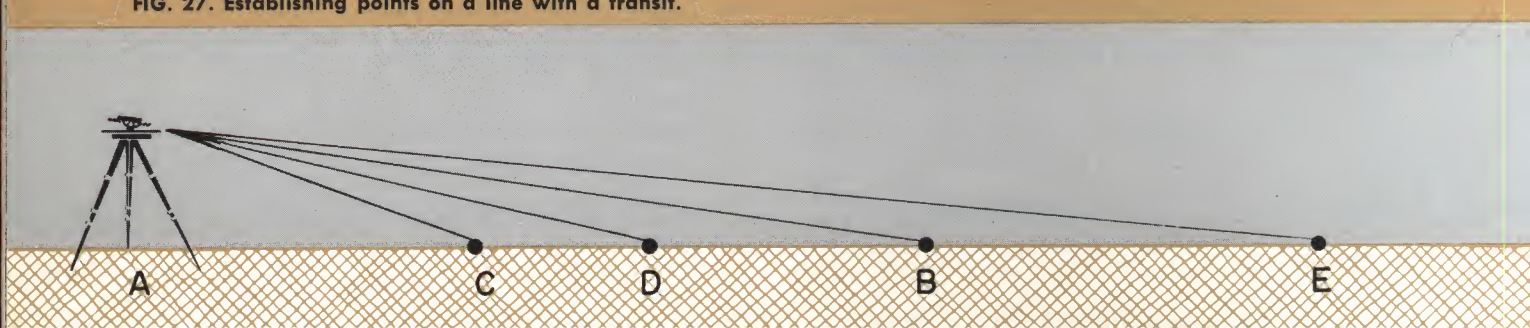


FIG. 27. Establishing points on a line with a transit.



constructing concrete flatwork

FIG. 28.

FIG. 29.

FIG. 30.

FIG. 31.

FIG. 32.

FIG. 33.

PREPARING THE SITE AND PLACING THE CONCRETE

Before placing any concrete the forms or screeds must be set to proper grade. The grade is sometimes determined by using a builder's level. The level is sighted on a measuring rod or rule that is set on an established grade (Fig. 28) and a reading is taken. Then the rod or rule is moved to where the form or screed will be placed (Fig. 29). With a stake in the ground at this point the rod or rule is raised or lowered until the desired grade is read by the level. A mark or nail is placed on the stake at the bottom of the rule (Fig. 30). This operation continues until enough stakes are set and marked with the proper grade and alignment.

A string line is then strung tightly from stake to stake at the marked position (Fig. 31). This string line will be at the top of the form or screed. The distance from the string line to the subgrade is checked to make sure there is enough depth to place the form or screed (Fig. 32). If not, the subgrade is dug out until there is enough clearance. The forms or screeds are then set to proper line and grade by following the string line (Fig. 33).

FIG. 34.

FIG. 35.

FIG. 36.

The forms or screeds are then well staked and braced. The stakes must be driven straight to ensure that the forms or screeds will be true and plumb. When the grade of a narrow walk is being established it is sometimes more convenient to set one edge form and then use a spirit level, as shown in Fig 34, to set the other edge form.

All sod and vegetable matter must be removed from the construction site and any soft or mucky places must be dug out, filled with at least 2 in. of granular material, such as sand, gravel or crushed stone, and thoroughly tamped (Fig. 35). Exceptionally hard compact spots must be loosened and then tamped to provide the same uniform support for the slab as the remainder of the subgrade.

When additional fills are required under walks, driveways or floors to bring them to the proper grade, the fills should also be of a granular material thoroughly compacted in a maximum of 4-in. layers. It is best to extend the top of all fills at least 1 ft. beyond the edges of walks and drives, and to make the slope of the fill flat enough to prevent undercutting during rains.

The top 6 in. of the subgrade should be of sand, gravel or crushed stone where subgrades are water soaked most of the time. These granular subgrades must be drained to prevent the collection of water. Well-compacted, well-drained subgrades do not require such special granular treatment.

Where a new concrete slab abuts an existing walk, driveway, building, curb, lighting standard, fireplug or other rigid object, a premolded material, usually 1/2 in. thick, should be placed at the joint. These joints are commonly called expansion joints. They are placed on all four sides of the square formed by the intersection of two walks. When the sidewalk fills the space between the curb and a building or wall, an expansion joint should be placed between the sidewalk and the curb and between the sidewalk and the building or wall. Expansion joints are not required at regular intervals in the sidewalk.

The concrete should contain only enough water to produce a concrete that has a relatively stiff consistency (Fig. 36) and works readily and does not segregate. Concrete should have a slump of about 3 in. when tested with a standard slump cone. The adding of more mixing water to produce a higher slump than specified lessens the durability and reduces the strength of the concrete.

In northern climates where concrete flat surfaces are subjected to freezing and thawing, air-entrained concrete is necessary. Air-entrained concrete is made by using an air-entraining portland cement or by adding an air-entraining agent during mixing.

Before the concrete is placed, the subgrade should be thoroughly dampened so that it is moist throughout,

but without puddles of water (Fig. 37).

Concrete should be placed between the forms or screeds as near to its final position as practicable. Precautions should be taken not to overwork the concrete while it is still plastic because an excess of water and fine material will be brought to the surface, which may lead to scaling or dusting later on.

The concrete should be thoroughly spaded along the forms or screeds to eliminate voids or honeycombs at the edges (Fig. 38).

FIG. 37.

FIG. 38.

FINISHING THE CONCRETE SURFACE

Any craftsman or tradesman should understand the nature and properties of the material with which he works. A cement mason should understand the nature of concrete, and the different problems in working with concrete made with the various types of portland cement.

Generally, all the dry materials used in making quality concrete are heavier than water. Thus, shortly after placement, these materials will have a tendency to settle to the bottom and force any excess water to the surface. This reaction is commonly called "bleeding." This bleeding usually occurs with non-air-entrained concrete. It is of utmost importance that the first operations of placing, screeding and darbying be performed before any bleeding takes place. The concrete should not be allowed to remain in wheelbarrows, buggies or buckets any longer than is absolutely necessary. It should be dumped and spread as soon as possible and struck off to proper grade, and then immediately screeded—followed at once by darbying. These last two operations should be performed before any free water has bled to the surface. The concrete should not be spread over a large area before screeding — nor should a large area be screeded and allowed to remain before darbying. *If any operation is performed on the surface while the bled water is present, serious scaling, dusting or crazing can result.* This point cannot be overemphasized and is the basic rule for successful finishing of concrete surfaces. (An explanation of the causes of scaling, crazing and dusting begins on page 30.)

The surface is struck off or rodded by moving a straightedge back and forth with a sawlike motion across the top of the forms or screeds. A small amount of concrete should always be kept ahead of the straightedge to fill in all the low spots and maintain a plane surface (Fig. 39).

FIG. 39.

FIG. 40.

On some jobs the next operation is using the hand tamper or jitterbug (Fig. 40). But this tool should be used sparingly and in most cases not at all. If used, it should be used only on concrete having a low slump (1 in. or less) to compact the concrete into a dense mass. Jitterbugs are sometimes used on industrial floor

construction because the concrete for this type of work usually has a very low slump, with the mix being quite stiff and perhaps difficult to work.

The hand tamper or jitterbug is used to force the large particles of coarse aggregate *slightly* below the surface in order to enable the cement mason to pass his darby over the surface without dislodging any large aggregate.

After the concrete has been struck off or rodded, and in some cases tamped, it is smoothed with a darby to level any raised spots and fill depressions (Fig. 41). Long-handled floats of either wood or metal, called bull floats, are sometimes used instead of darbies to smooth and level the concrete surface (Fig. 42).

When all bled water and water sheen has left the surface and the concrete has started to stiffen, it is time for the other finishing operations. Where edging is necessary (Fig. 43), this could be the next operation. This produces a rounded edge or radius on the edge of the slab to prevent chipping or damage to the edge of the concrete slab. The edger should be run back and forth until a finished edge is produced. The cement mason should be careful that all coarse aggregate particles are covered and that the edger does not leave too deep an impression in the top of the slab, otherwise the indentation may be difficult to remove with subsequent finishing operations.

Immediately following edging, the slab is jointed (or grooved). The cutting edge or bit of the jointing tool cuts joints in the slab called control or contraction joints. These joints are used to control any cracking tendency in the concrete that may be due to shrinkage stresses caused by drying out or by temperature changes. The joints provide a reduction in slab thickness and thus create a weakened section that induces cracking to occur at that location. When the concrete shrinks, the cracks in these joints can open slightly, thus preventing irregular and unsightly random cracks. In sidewalk and driveway construction the tooled joints are usually spaced at intervals equal to the width of the slab (Fig. 44), but not more than 20-ft. intervals. For control joints the jointer should have a 3/4-in. bit. If the slab is to be grooved only for decorative purposes, jointers having shallower bits may be used.

It is good practice to use a straight 1x8 or 1x10 board as a guide when making the groove in the concrete slab. If the board is not straight it should be planed true. The tooled joints should be perpendicular to the edge of the slab. The same care must be taken in running joints as in edging, for a tooled joint can add to or detract from the appearance of the finished slab.

On large concrete flat surfaces it may be more convenient to cut joints with an electric or gasoline-driven power saw fitted with an abrasive or diamond blade (Fig. 45). Joints made with a power blade should be

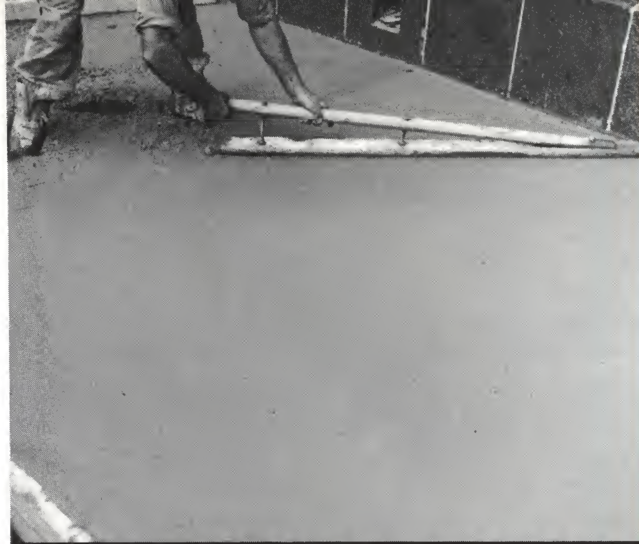


FIG. 41.

FIG. 42.

FIG. 43.

FIG. 44.

FIG. 45.

FIG. 46.

FIG. 47.

cut within 4 to 12 hours after the slab has been placed and finished. Cutting of joints must be done as soon as the concrete surface is firm enough not to be torn or damaged by the blade, and before random shrinkage cracks can form in the concrete slab.

After edging and hand jointing operations, the slab should be floated. Many variables—concrete temperature, air temperature, relative humidity, wind, etc.—make it difficult to set a definite time to begin floating. This knowledge comes only through a great deal of on-the-job experience.

The purpose of floating is threefold: (1) to embed large aggregates just beneath the surface; (2) to remove slight imperfections, humps and voids to produce a level or plane surface; (3) to consolidate mortar at the surface in preparation for other finishing operations.

Aluminum or magnesium floats should be used, especially on air-entrained concrete. This type of metal float greatly reduces the amount of work required by the finisher, because the drag is reduced and the float slides more readily over the concrete surface, but still has a good floating action. A wood float tends to stick to and tear the concrete surface. The light metal float forms a smoother surface texture than the wood float.

The marks left by the edger and jointer should be removed by floating (Fig. 46) unless such marks are desired for decorative purposes, in which case the edger or jointer should be rerun after the floating operation.

Immediately following floating, the surface should be steel-troweled. It is customary for the cement mason to float and then steel-trowel an area before moving his knee boards (Fig. 47). If necessary, tooled joints and edges should be rerun before and after troweling to maintain uniformity or to remove kinks.

The purpose of troweling is to produce a smooth, hard surface. For the first troweling, whether by power or by hand, the trowel blade must be kept as flat against the surface as possible. If the trowel blade is tilted or pitched at too great an angle, an objectionable "washboard" or "chatter" surface will result. For first troweling a new trowel is not recommended. An older trowel which has been "broken in" can be worked quite flat without the edges digging into the concrete. The smoothness of the surface could be improved by timely additional trowelings. There should necessarily be a lapse of time between successive trowelings in order to permit concrete to increase its set. As the surface stiffens each successive troweling should be made by smaller-sized trowels to enable the cement mason to use sufficient pressure for proper finishing.

The steel-troweled surface leaves the concrete very smooth. However, such surfaces become quite slippery when wet and should be slightly roughened to produce a nonslip surface. This can be done by brushing or brooming the surface. The brushed surface is made by

drawing a soft-bristled push broom with a long handle over the surface of the concrete slab after steel-troweling. Note in Fig. 48 that the workman is drawing the broom right over the joint, but the joint is not being marred. This indicates that the concrete surface has been steel-troweled properly and is hard enough so the edges of the joint will not be damaged.

When coarser textures are desired, because of steep slopes, a stiffer bristled broom may be used. Other types of surface finishes, such as exposed aggregate, color and geometric design will be discussed in a later section.

FINISHING AIR-ENTRAINED CONCRETE

Air entrainment gives concrete a somewhat altered consistency that requires a little change in finishing operations from those used with non-air-entrained concrete.

Air-entrained concrete contains microscopic air bubbles that tend to hold all the materials in the concrete, including water, in suspension. This type of concrete requires less mixing water than non-air-entrained concrete, and still has good workability with the same slump. Since there is less water and it is held in suspension, little or no bleeding occurs. This is the reason for slightly different finishing procedures. With no bleeding, there is no waiting for the evaporation of free water from the surface before starting floating and troweling. This means that in general floating and troweling should be started sooner—before the surface becomes too dry or tacky. If floating is done by hand, the use of an aluminum or magnesium float is essential. A wood float drags and greatly increases the amount of work necessary to accomplish the same result. If floating is done by power there is practically no difference between finishing procedures for air-entrained and non-air-entrained concrete, except that we may start floating sooner on the air-entrained concrete.

Practically all horizontal surface defects and failures are caused by finishing operations performed while bled water or excess surface moisture is present. Better results are generally accomplished, therefore, with air-entrained concrete.

CURING

Curing of a concrete slab is one of the most important construction operations, but is often one of the most neglected. Concrete properly mixed, placed and finished will still result in a poor job if proper curing operations are not followed.

Concrete should be protected so that little or no moisture is lost during the early stages of hardening. Newly placed concrete should not be permitted to dry out too fast and must be protected from the sun and drying winds. This may be done with burlap or canvas coverings kept continuously wet. As soon as the concrete has hardened enough so that the surface will not be marred, the burlap or canvas can be replaced with coverings of earth, sand or straw kept moist for at least 3 days by occasional sprinkling. Another method of moist curing is by ponding, which is done by keeping an inch or so of water on the concrete surface. The water can be confined by earth dikes around the edges of the slab. Watertight paper or polyethylene film are also widely used for coverings. Laps in such coverings should be taped to prevent moisture loss. Membrane curing compounds sprayed on the surface of the concrete are often used and should be applied immediately after the concrete has been given its final finish (Fig. 49). Adequate and uniform coverage by curing compounds is essential, and in some cases two applications may be required. Additional information on curing is given in later sections on hot and cold weather concreting.

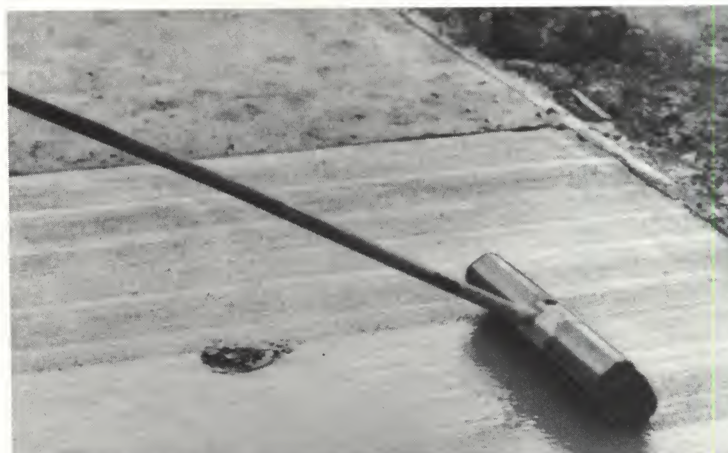


FIG. 48.

FIG. 4

hot weather concreting

Concreting in hot weather poses some special problems. Among these are strength reduction and cracking of flat surfaces due to rapid drying. Concrete may stiffen before it can be consolidated because of rapid setting of the cement and excessive absorption and evaporation of mixing water. This leads to difficulty in the finishing of flat surfaces.

Most of these problems can be minimized by the following precautions:

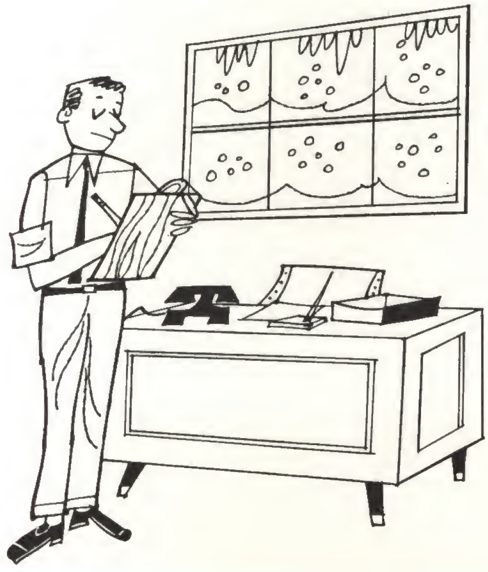
1 PLAN AHEAD

Be prepared with necessary equipment and material well in advance of hot weather.

Be sure of an ample water supply for sprinkling subgrades, wood forms and aggregates, and for curing.

Have tarpaulins or polyethylene sheets and lumber ready for sunshades and windbreaks.

Schedule work so that concrete can be placed with the least delay. Jobs could be started late in the afternoon during extremely hot periods.



2 USE COOL MATERIALS

Use concrete which has been chilled during preparation. Stockpiles of coarse aggregate should be sprinkled with water to cool the aggregate by evaporation. Mixing water should be chilled in very hot weather by refrigeration or by using ice as part of mixing water. The ice should be melted by the time concrete leaves the mixer.

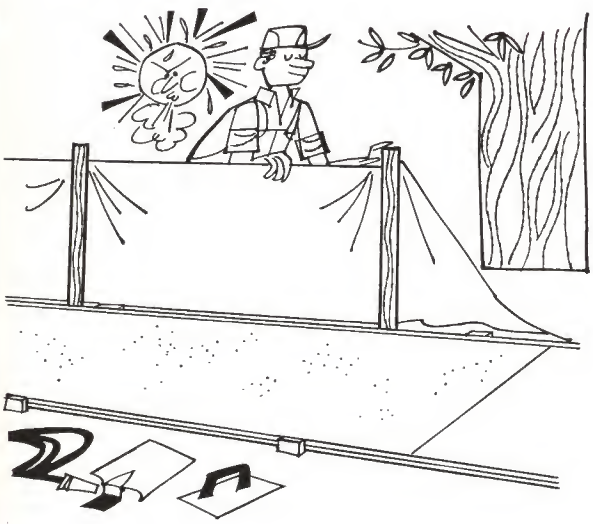
3 PREVENT ABSORPTION

Sprinkle subgrade and wood forms just before placing concrete so they will not absorb water from the mix.

Coarse aggregates should be sprinkled before they are added to the batch.

4 PROTECT AGAINST EVAPORATION

Erect windbreaks to prevent strong, hot winds from drying exposed concrete flatwork surfaces while they are being finished.



5 PLACEMENT AND FINISHING

Don't delay in placing concrete. Strike it off and darby it at once.

Place temporary covers, such as burlap kept continuously wet, over the fresh concrete immediately after striking and darbying.

When ready for final finishing, uncover only a small section immediately ahead of the finishers. Cover again at once after final finish and keep the cover wet.

Any delays in finishing air-entrained concrete in hot weather usually lead to the formation of a rubber-like surface which is difficult to finish without leaving ripples or ridges.

6 CURE IMMEDIATELY

Start curing as soon as surfaces are hard enough to resist marring.

If curing compound is to be used, apply it immediately after final finishing. See that adequate and uniform coverage is obtained. In extremely hot weather it is advisable to cover the slab with water for 12 hours before using curing compound.

Keep the concrete surface *constantly* wet to avoid alternate wetting and drying during the curing period.

Continue curing for at least 7 days. Water not only acts as a curing agent but also cools the slab.

cold weather concreting

After concrete is in place it should be protected against freezing. The strength of concrete that has been subjected to a single freezing cycle at an early age can be restored to normal by resumption of favorable curing conditions. But such concrete will not have the resistance to weathering nor will it be as watertight as concrete that has not been frozen. Where several cycles of freezing and thawing occur at an early age, strength and other qualities are permanently affected. This is one of the reasons why such flatwork as sidewalks and driveways placed late in the fall sometimes deteriorate within a few years. Most problems can be minimized by the following precautions:

1 PLAN IN ADVANCE

Have equipment and materials ready before cold weather arrives.

Provide heaters, insulating materials and enclosures.

Use high-early-strength concrete where job conditions make it desirable.

2 HEAT THE MATERIALS

The temperature of the concrete as it is placed in the forms should be between 50 and 70 deg. F. for slabs.

When air temperatures are between 30 and 40 deg. F., the mixing water should be heated.

When air temperatures are below 30 deg. F., the mixing water and sand (and sometimes coarse aggregate) should be heated.

No frozen aggregate lumps should be in concrete at the time it is placed.

To prevent flash set, materials should not be overheated. Maximum allowable water temperature is about 140 deg. F.

Do not place concrete on frozen ground—unequal settling will occur when the ground thaws.

Fresh excavations should be covered with straw or other insulating material to prevent the ground from freezing until concrete can be placed.

Remove all ice and frost from forms and steel reinforcing.

3 USE ACCELERATORS CAREFULLY

Use about 1 lb. of calcium chloride per sack of cement to hasten hardening. Not more than 2 lb. should ever be used because of danger of flash set.

Don't use any admixtures to prevent concrete from freezing.

Don't use calcium chloride with other admixtures which accelerate hardening.

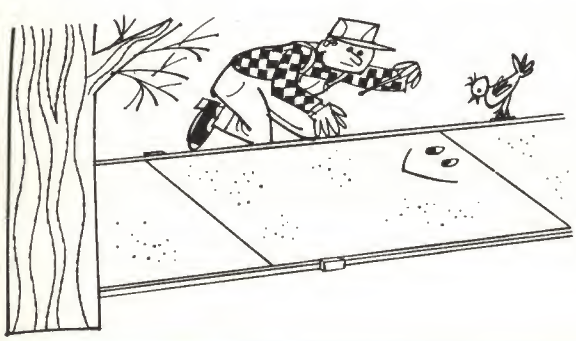
4 PROVIDE SUITABLE CURING TEMPERATURES

Maintain temperature of concrete, when using normal portland cement, at 70 deg. F. for 3 days or 50 deg. F. for 5 days.

Maintain temperature of high-early-strength concrete at 70 deg. F. for 2 days or 50 deg. F. for 3 days.

Do not allow concrete to freeze during next 4 days.

Cool concrete *gradually* at rate of 1 to 2 deg. per hour until it reaches the outside temperature.



6 PROTECT CONCRETE

Insulation, such as with a thick blanket of straw, without artificial heat is often sufficient protection for slabs on ground.

At lower temperatures housing and artificial heat are necessary.

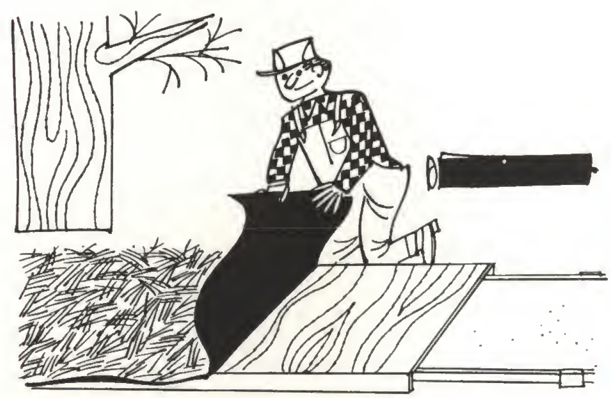
Housings can be made of wood, insulation board, waterproofed paper or tarpaulins over wood frames.

Circulate moist warm air between floor slabs and housing.

Avoid the risk of fire by placing coke or oil-fired heating units away from flammable material. Vent to outside.

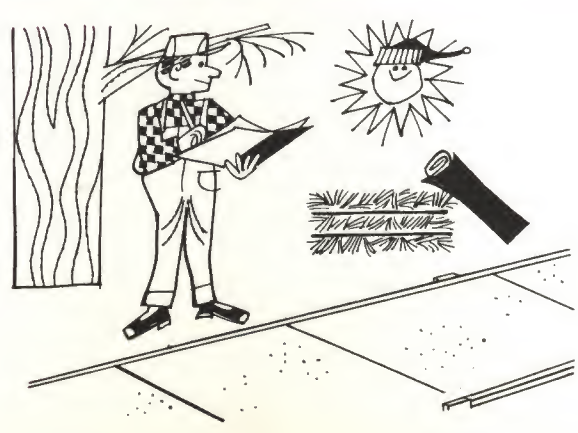
Raise heating units above the floor to avoid rapid drying of concrete underneath.

Keep concrete moist, especially near heating units. In cold weather when artificial heat is applied, moisture for curing is still very important. First wet the slab well with water and cover with waterproof paper. Then apply heat to keep from freezing. This water treatment, along with covering, prevents the surface of the slab from drying out.



5 KEEP JOB CONDITION RECORDS

Record date, hours, weather conditions and temperature (both of air surrounding concrete and surface of concrete) at least twice daily.



special surface finishes

EXPOSED AGGREGATE

A colorful exposed-aggregate surface is often chosen for patios, garden walks, perimeter walks around swimming pools, and driveways (Fig. 54)—or for any area where a decorative, rustic effect is desired. If the surface is ground and polished it is especially suitable for such places as entrances, interior patios and recreation rooms.

The selection of the aggregates is highly important and test panels should be made before the job is started. Colorful gravel aggregate, quite uniform in size—usually ranging from 1/2 in. to 3/4 in.—is recommended. Avoid flat, sliver-shaped particles or aggregate less than 1/2 in. in diameter because they may not bond properly or may become dislodged during exposing operations. Exposing the aggregate used in ordinary concrete is generally unsatisfactory, since this will just give an unattractive, rough concrete surface.

A 5½- to 6-sack concrete with a maximum slump of 3 in. should be used. Immediately after the slab has been screeded and darbied, the selected aggregate should be scattered by hand and evenly distributed so that the entire surface is completely covered (Fig. 50). The initial embedding of the aggregate is usually done by patting with a darby or the flat side of a 2x4 (Fig. 51). After the aggregate is quite thoroughly embedded, and as soon as the concrete will support the weight of a mason on kneeboards, the surface should be hand floated using a magnesium float or darby (Fig. 52). This operation should be performed so thoroughly that all aggregate is entirely embedded just beneath the surface. The grout should completely surround and slightly cover all aggregate, leaving no holes or openings in the surface.

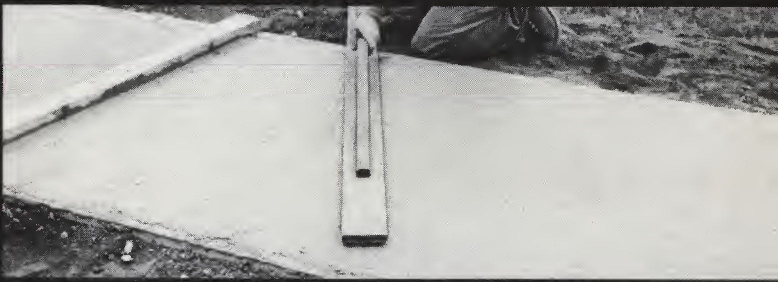
Shortly following this floating a reliable retarder may be sprayed or brushed over the surface, following the manufacturer's recommendations. On small jobs a retarder may not be necessary. Retarders are generally used on large jobs for better control of exposing operations. Where a retarder has been used, exposing of the aggregate is usually done some hours later by brushing and hosing with water. However, the manufacturer's recommendations should be followed closely.

FIG. 50. The selected, decorative aggregate is distributed to cover the entire surface evenly.

FIG. 51. The initial embedding of the aggregate.

FIG. 52. Darbying the surface to completely cover the aggregate with grout.

FIG. 53. Exposing the aggregate is done by simultaneously brushing and hosing with water.



Whether or not a retarder has been used, the proper time for exposing the aggregate is quite critical. It should be done as soon as the grout covering the aggregate can be removed by simultaneously brushing and hosing with water (Fig. 53), yet not overexpose or dislodge the aggregate. If, during exposing, it is necessary for masons to move about on the surface, kneeboards should be used gently. If possible, this should be avoided because of the risk of breaking aggregate bond.

For interior areas, or where a smooth surface is desired, no retarder is used and exposure of the aggregate is accomplished entirely by grinding. This may be followed by polishing, which will give a surface similar to terrazzo.

Because the aggregate completely covers the surface, tooled joints in this type of work are quite impractical. Decorative or control joints are best accomplished by sawing. Control joints should be cut from 4 to 12 hours after the slab is placed. They should be at least one-fifth the depth of the slab. A small-radius edger should be used before and immediately after the aggregate has been embedded to provide a more attractive edge to the slab. Another method of providing control joints is to install permanent strips of redwood before placing concrete.

In another method of placement, a top course containing the special aggregate and usually 1 in. or more thick, is specified.

Exposed-aggregate slabs should be cured thoroughly. Care should be taken that the method of curing used does not stain the surface. Straw, earth and some types of building paper may cause staining.

DRY-SHAKE COLOR SURFACE

This is a colored concrete surface that may be used for showrooms, schools, churches, patios, decorative walks, driveways or any areas where a colored surface is desired.

It is made by applying a dry-shake material that may be purchased from various reliable manufacturers ready for use. Its basic ingredients are mineral oxide pigment (none other should be used), white portland cement and specially graded silica sand or fine aggregate. Job selecting, proportioning and mixing of a dry-shake material is not recommended.

After the concrete has been screeded and darbied, and free water and excess moisture have evaporated from the surface, the surface should be floated, either by power or by hand float. If by hand, a magnesium or aluminum float should be used. Preliminary floating should be done before the dry-shake material is applied to bring up enough moisture for combining with this dry material. Floating also removes any ridges or depressions that might cause variations in color intensity. Immediately following this floating operation, the dry-shake material is shaken *evenly* by hand over the surface. If too much color is applied in one spot, nonuniformity in color and possibly surface peeling will result.

FIG. 54. When completed the exposed aggregate surface adds to the beauty of a home.

The first application of the colored dry-shake should use about two-thirds of the total amount needed (in pounds per square foot as specified). In a few minutes this dry material will absorb some moisture from the plastic concrete, and should then be thoroughly floated into the surface, preferably by a power float. Immediately following this, the balance of the dry-shake should be distributed evenly over the surface. This should also be thoroughly floated and made part of the surface, taking care that a uniform color is obtained.

All tooled edges and joints should be "run" before and after the applications.

Shortly after the final floating operation, the surface should be power troweled. If work is being done by hand, troweling should immediately follow the final floating. After the first troweling, whether by power or by hand, there should be a lapse of time—the length depending upon such factors as temperature, humidity, etc.—to allow the concrete to increase its set. After this lapse of time, the concrete may be troweled a second time to improve the texture and also produce a denser, harder surface.

For exterior surfaces, a second troweling is usually sufficient. Then a fine, soft-bristled push broom may be drawn over the surface to produce a roughened texture for better traction under foot. Smooth surfaces are slippery and hazardous when wet. For interior surfaces a third hard troweling could be specified. This final troweling should be done by hand to eliminate any washboard or trowel marks. This final hand troweling produces a smooth, dense, hard-wearing surface.

Colored slabs, as with other types of freshly placed concrete, must be cured thoroughly.

After thorough curing and surface drying, interior surfaces may be given at least two coats of special concrete floor wax containing the same mineral oxide pigment used in the dry-shake. This wax is also available from various reliable manufacturers. Care should be taken to avoid any staining, such as by dirt or foot traffic, during the curing or drying period and before waxing.

GEOMETRIC DESIGN

The concrete surface may be scored or tooled with a jointer in various decorative patterns. This is commonly done for patios, garden walks and areas around swimming pools.

After the concrete has been screeded and darbied and excess moisture has left the surface, it should be scored in random geometric designs. This may be done by using a jointer or groover, or a bent piece of 1/2- or 3/4-in. pipe, preferably copper, about 18 in. long (Fig. 55). The random scoring by the pipe tool appears as recessed joints in the slab. The tool is similar in shape to the S-shaped jointing tool used in masonry work. One radius end of this is worked into the concrete to produce a scoring approximately 3/4 to 1 in. wide and 3/8 in. deep. This should be done while concrete is still very plastic, allowing coarse aggregate to be pushed aside by the tool and embedded into the slab. The first jointing operation will leave burred edges. After the excess moisture or water sheen has disappeared, the entire area should be floated and the jointing tool run again to produce neat joints. Then the surface should be carefully troweled (Fig. 56). After the concrete has set sufficiently, it should be lightly brushed with a very fine-bristled broom. The joints may be cleaned by brushing with a soft-bristled paint brush (Fig. 57). No water is to be used during brushing operations.

The concrete should be thoroughly cured.

LEAF IMPRESSION

This is a special surface which may be used as a border around a patio or along the edges of a garden walk. It is a highly decorative design and adds interest as a conversation piece.

Leaves are taken from local trees, preferably from those on the premises. Immediately after the concrete has been floated and troweled, the leaves should be pressed carefully, stem side down, into the freshly troweled concrete. This is most easily done by using a cement mason's finishing trowel. The leaves should be so completely embedded that they may be troweled over without dislodging them, but no mortar should be deposited over the leaves (Fig. 58). After the concrete has set sufficiently, the leaves are removed.

Thorough curing is necessary after the concrete has set so the surface will not be marred.

FIG. 55. Random scoring using a piece of S-shaped copper tubing.

FIG. 56. Troweling the surface.

FIG. 57. Adding the finishing touches with a soft-bristled paint brush.

FIG. 58. Making leaf impressions in the surface with a finishing trowel.

CIRCLE DESIGN

This is an interesting surface that can be used in many ways, such as a border around a patio slab, over the entire concrete slab, or in alternate squares. Circles of different sizes and overlapping circles add interest.

After the concrete has been placed, struck off, darbied, floated and steel troweled, the surface is ready to be given the circle design.

Using any number of circular-shaped cans of various sizes (starting with the largest size chosen), press the open end of the can into the freshly troweled surface and give the can a slight twist to ensure a good impression. After making a number of large circle impressions, take the next size can and repeat the operation. Continue this until the desired number and sizes of circle impressions have been made (Fig. 59).

If the slab is exposed to the weather, the surface should be given a lightly brushed nonskid finish.

The slab must be moist cured.

SWIRL DESIGN

A nonskid surface texture that can be decorative as well as functional is the swirl design.

This swirl texture can be produced on a slab by using a magnesium or aluminum float or a steel finishing trowel. When a float is used the finish is called a swirl float finish, and when a trowel is used the finish is called a swirl trowel finish.

After the concrete surface has been struck off, darbied, floated and steel troweled, the surface is ready to be given either the swirl float or swirl trowel finish.

The float should be worked flat on the surface in a semicircular or fan-like motion. Pressure applied on the float with this motion will give a rough-textured swirl design as shown in Fig. 60.

With the same motion but using a steel finishing trowel, held flat, the cement mason can obtain a finer textured swirl design on the concrete surface (Fig. 61).

Moist curing of the slab is the final operation.

WAVY BROOM DESIGN

The wavy broom design may be used to add interest to a nonskid textured surface. This design is given to the surface after all the conventional operations of striking off, darbying, floating and troweling have been done. The broom is drawn across the slab in a wavy motion (Fig. 62). The coarse texture is obtained by using a stiff-bristled broom; a finer texture may be achieved by using a soft-bristled broom.

After the concrete has set sufficiently so that this surface texture will not be marred, the slab must be moist cured.

KEYSTONE FINISH

This is a special finish which has a travertine-like texture. It can be used for a patio, garden walk, driveway,

FIG. 59. Making a circle design on a concrete surface.

FIG. 60. Swirl design on a concrete surface made with an aluminum float.

FIG. 61. Swirl design on a concrete surface made with a steel finishing trowel.

FIG. 62. Wavy broom design on a concrete surface made with a stiff-bristled broom.

FIG. 63. Travertine finish, commonly called keystone finish.

FIG. 64. This random-scored keystone finish makes an attractive patio area.

perimeter around a swimming pool or any location where an unusually decorative flat concrete surface is desired.

After the concrete slab has been struck off, darbied and edged in the usual manner, the slab is broomed with a stiff-bristled broom to ensure bond when the finish (mortar coat) is applied.

The finish coat is made by using prepared dry-shake materials. (See DRY-SHAKE COLOR SURFACE section on page 26.) An alternate method is to mix 1 sack of white portland cement and 2 cu.ft. of sand with about 1/4 lb. of color pigment (usually yellow is used to tint the mortar coat, but any mineral oxide color may be used). Care must be taken to keep the proportions exactly the same for all batches. Enough water is added to make a soupy mixture having the consistency of thick paint.

This mortar is placed in pails and thrown vigorously on the slab with a dash brush to make an uneven surface with ridges and depressions. The ridges should be about 1/4 to 1/2 in. high. The surface is allowed to harden enough to permit a cement mason on it with kneeboards.

The slab is then troweled with a steel trowel to flatten the ridges, leaving the slab surface smooth in some places and rough or coarse grained in the low spots. Depending upon the amount of mortar thrown on the slab and the amount of troweling done on this mortar coat, many interesting textures can be produced (Figs. 63 and 64). The slab should then be scored into random geometrical designs before curing.

concrete surface defects

There are many causes for concrete surface defects. Some of the major defects, their causes and the construction techniques which should be used to prevent them are described as follows:

scaling

Scaling is when the surface of a hardened concrete slab breaks away from the slab to a depth of about 1/16 to 3/16 in. This usually occurs at an early age of the slab.

	CAUSES		PREVENTIVE MEASURES
1	Early cycles of freezing and thawing of the surface of newly placed concrete.	1	The temperature of freshly placed concrete should be maintained above 50 deg. F. for at least 5 days when using normal portland cement and above 50 deg. F. for at least 3 days when using high-early-strength portland cement.
2	Cycles of freezing and thawing when non-air-entrained concrete was used.	2	Use air-entrained concrete.
3	Applications of de-icing salts when non-air-entrained concrete was used.	3	Use air-entrained concrete.
4	Faulty workmanship. Any one of the finishing operations — screeding, darbying, floating or troweling—performed while free water or bled water is on the surface, will cause scaling. Mixing this excess water into the top of the slab will cause a segregation of the surface fines (sand and cement) and cause scaling. It will also cause a thin layer of neat cement, clay and silt to be brought to the surface. Just under this layer will be another layer of nearly clean washed sand which is not bonded to the concrete under it.	4	No finishing operation should ever be performed while free water is present. Water should be allowed to evaporate from the surface, or be forced to evaporate by fans or blower-type heaters, or it should be removed by dragging a rubber garden hose over the surface.

crazing

Crazing is the occurrence of numerous fine hair cracks in the surface of a newly hardened slab due to surface shrinkage. These cracks form an overall pattern similar to a crushed eggshell.

CAUSES	PREVENTIVE MEASURES
1 Rapid surface drying usually caused by either high air temperatures, hot sun or drying winds, or a combination of any of these.	**1** Apply fog spray or cover with burlap or canvas immediately after screeding and darbying. Keep surface covered with burlap or canvas kept continuously damp until ready for floating and troweling. Moist cure as soon as possible without marring the surface. For high temperatures or hot sun, some form of curing with water should be used since it will maintain or lower the concrete surface temperatures.
2 Premature floating and troweling. Floating and troweling when there is an excess amount of moisture at the surface or while concrete is still too plastic. Premature floating and troweling brings an excess amount of fines and moisture to the surface. A rapid loss of this moisture will cause shrinkage at the surface, which may result in crazing.	**2** Do not start floating and troweling until excess moisture has evaporated from the surface, and the concrete has started its initial set. To avoid excess moisture, reduce the slump and use air-entrained concrete.
3 Overuse of the jitterbug, vibrating screed, darby or bull float may contribute by working an excess of mortar to the surface.	**3** Use these tools sparingly. Because the excess mortar at the surface tends to cause additional surface shrinkage, delayed floating and troweling operations are required for proper compaction.

dusting

The appearance of a powdery material at the surface of a newly hardened concrete slab is called dusting.

CAUSES	PREVENTIVE MEASURES
1 An excess of clay or silt in the concrete. These harmful fines mix with the sand and cement at the surface and result in dusting.	**1** Use clean and well-graded coarse and fine aggregate.
2 Premature floating and troweling. Premature floating, in particular, mixes excess surface water with the surface fines, thereby weakening the strength of the cement paste.	**2** Delay floating and troweling until all free water or excess moisture have disappeared and concrete has started its initial set.
3 Carbon dioxide from open salamanders or gasoline engines, power buggies or mixer engines. When this gas comes into contact with the surface of plastic concrete, a reaction takes place which impairs proper hydration.	**3** Vent salamander fumes to the outside. Provide sufficient ventilation.
4 Condensation on the surface before floating and troweling operations have been completed. This usually occurs in the spring and fall when materials become cold due to low night temperatures and no provisions have been made for heating the materials. If the temperature of all these materials is approximately 45 deg. F. the concrete will also be approximately 45 deg. F. If this concrete is placed indoors, for example, where it will get no heat from the sun (basement floors and indoor slabs on	**4** If possible, this condition of condensation should be anticipated and the concrete should be heated, or at least hot water should be used for mixing. If this is impossible, use blower-type heaters to lower the humidity directly over the slab and use fans to increase the circulation of air. If heaters and fans are not available, open all windows and doors to increase circulation of air. While condensation is still present, floating and troweling operations should be held to a minimum and the surface

grade), the temperature of the concrete will rise very slowly, and setting is greatly retarded. If air temperature should rise substantially during the day, and the humidity is relatively high, moisture will usually condense on the slab. Floating and troweling of this excess water into the surface causes dusting.

should not be given a second troweling. The use of neat cement as a dry-shake should not be permitted, nor should any mixture of cement and *fine* sand be used as a dry-shake. Since condensation may occur for several hours, and the concrete is beginning to harden, emergency measures must be taken in order to finish the slab. As an emergency a dry mixture of one part of portland cement and one part of well-graded concrete sand should be well mixed and evenly and lightly distributed over the surface. This should be *immediately* floated thoroughly into the surface and followed *at once* by troweling. There should be no second troweling, since additional condensation would take place after the first troweling. This problem of condensation is not uncommon, but very few cement masons or superintendents realize when it is happening.

5 Dry heat from winter-protection heaters will lower the relative humidity around the concrete excessively. Concentration of heat on freshly placed concrete will inhibit proper hydration of the cement, resulting in weak concrete and dusting surface.

5 Water jackets should be placed on heaters to increase the relative humidity by evaporation, and any one of the acceptable methods of moist curing should be employed. Location of heaters should be changed periodically so that no area will be subjected to an extreme or harmful amount of heat.

6 No curing or inadequate curing.

6 Proper curing for the specified length of time is essential. Concrete which is not cured will often be weak and the surface easily worn by foot traffic.

reference list

Manual of Concrete Inspection, American Concrete Institute.

Concrete Manual, U.S. Bureau of Reclamation.

Standard for Recommended Practice for Selecting Proportions for Concrete (ACI 613-54), American Concrete Institute.

Standard for Recommended Practice for Measuring, Mixing and Placing Concrete (ACI 614-42), American Concrete Institute.

Standard for Recommended Practice for Winter Concreting (ACI 604-56), American Concrete Institute.

Standard for Recommended Practice for Hot Weather Concreting (ACI 605-59), American Concrete Institute.

Design and Control of Concrete Mixtures, Portland Cement Association.

A Practical Course in Concrete, Portland Cement Association.

Organizations concerned with concrete are usually referred to by their initials. Listed below are initial designations followed by full names and addresses of these organizations.

ACI	American Concrete Institute, P.O. Box 4754, Redford Station, Detroit 19, Mich.
ASTM	American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.
NRMCA	National Ready Mixed Concrete Association, 900 Spring St., Silver Spring, Md.
PCA	Portland Cement Association, 33 West Grand Ave., Chicago 10, Ill.
USBR	U.S. Bureau of Reclamation, Denver Federal Center, Denver 2, Colo.

specifications and test methods

ASTM C 150	Standard Specifications for Portland Cement
ASTM C 175	Standard Specifications for Air-Entraining Portland Cement
ASTM C 205	Tentative Specifications for Portland Blast-Furnace Slag Cement
ASTM C 340	Tentative Specifications for Portland-Pozzolan Cement
ASTM C 33	Standard Specifications for Concrete Aggregates
ASTM C 260	Tentative Specifications for Air-Entraining Admixtures for Concrete
ASTM C 233	Tentative Method of Testing Air-Entraining Admixtures for Concrete
ASTM D 98	Tentative Specifications for Calcium Chloride
ASTM C 171	Tentative Specifications for Waterproof Paper for Curing Concrete
ASTM 309	Standard Specifications for Liquid Membrane Forming Compounds for Curing Concrete
ASTM C 172	Standard Method of Sampling Fresh Concrete
NRMCA 47	Specifications and Test Methods for Ready-Mixed Concrete
ASTM C 143	Standard Method of Test for Slump of Portland Cement Concrete
ASTM C 360	Tentative Method of Test for Ball Penetration in Fresh Portland Cement Concrete
ASTM C 231	Tentative Method of Test for Air Content of Freshly Mixed Concrete by Pressure Method
ASTM C 173	Standard Method of Test for Air Content of Freshly Mixed Concrete by the Volumetric Method
ASTM C 31	Standard Method of Making and Curing Concrete Compression and Flexure Test Specimens in the Field
ASTM C 94	Standard Specifications for Ready-Mixed Concrete
ASTM C 125	Standard Definitions of Terms Relating to Concrete and Concrete Aggregates

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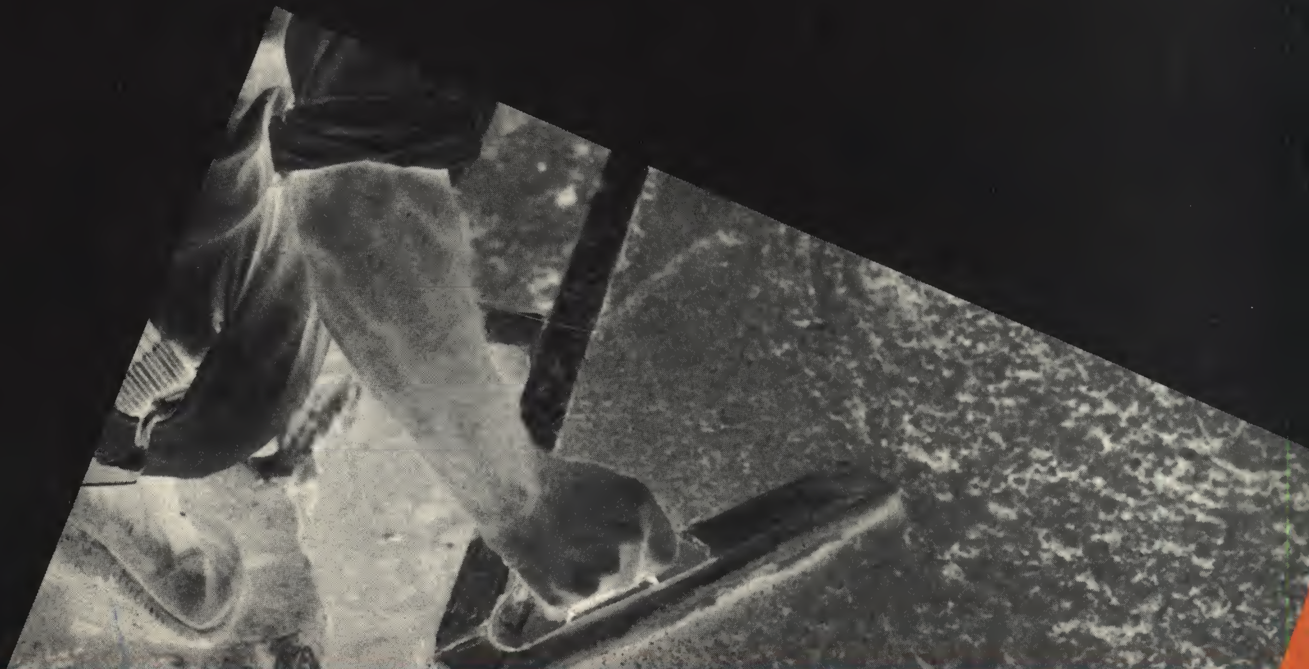

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